Technical Memorandum
Hite Marina Siltation Study
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INTRODUCTION

The National Park Service and ARAMARK Sports and Entertainment Services, Inc. retained a team of consultants led by EDAW, and including Mussetter Engineering, Inc. (MEI), to develop an updated Development Concept Plan, (DCP) and associated Environmental Assessment (EA) for Hite Marina, Lake Powell, Glen Canyon National Recreation Area (NRA) (Figure 1). The purpose of the DCP is to guide future development of services, facilities, and infrastructure for the National Park Service (NPS) for the next 10+ years. One of the primary objectives of the updated DCP is to determine whether it is economically feasible to continue to invest in the development of Hite based on its predicted future life as a marina location. MEI performed a study of future siltation rates in the vicinity of the marina to aid in this determination. This technical memorandum presents the results of that study, including a summary of the methods and assumptions on which the results are based.

In completing the siltation study, MEI performed the following tasks:

- Existing data relating to historic siltation rates in Lake Powell were obtained and evaluated. This data included a report on the 1986 Lake Powell Survey that was conducted by the U.S. Bureau of Reclamation (USSR, 1988), additional data from that study obtained directly from the USBR by MEI that was not included in the report, historic water inflow data, historic Lake Powell water-surface elevation data and other anecdotal information regarding siltation patterns near the head of Lake Powell.

- A bathymetric survey of the reservoir in the vicinity of Hite Marina was, conducted by MEI in March 28-29, 2000, to provided more recent data on the siltation patterns in this area.

- The available data were analyzed to provide an estimate of the future siltation rates in the vicinity of the marina.

Background and Existing Data

Construction of Glen Canyon Dam began in 1957, and was completed in 1964. Filling of Lake Powell upstream from the dam actually commenced on March 13, 1963, with closure of the diversion tunnels. The reservoir has a total length of about 190 miles, and it first reached its full capacity at an elevation of 3700 feet on June 22, 1980 (Figure 2). Hite Marina is located in the upstream portion of the reservoir approximately 155 miles upstream from Glen Canyon Dam near the confluence of the Colorado and Dirty Devil Rivers (Figures 1 and 3).

Sediment that is carried into Lake Powell by the Colorado River and its tributaries deposits near the head of the reservoir forming a downstream-progressing delta. As

of 1986, the top of the sediment wave that forms the delta had passed the mouth of Dark Canyon, approximately 165 miles upstream from the dam, with the foreset of the delta extending downstream approximately 25 miles to within about 10 miles of Good Hope Bay (Figure 4) (USBR, 1988). The USBR survey on which Figure 4 is based included 409 range-lines (approximately one per mile), which were established along the entire length of the reservoir as well as all major tributaries. The survey results indicated that about 868,230 acre-feet of sediment had deposited below elevation 3700 feet between dam closure in 1963 and 1986, of which 54 percent (approximately 472,000 acre-feet) had deposited in the Colorado River and the remainder in the San Juan River and remaining tributaries (USBR, 1988). These estimates equate to, an annual sedimentation rate in the Colorado River of about 20,000 acre-feet during the 24-year period. The sediment elevation in the bottom of the reservoir in the vicinity of Hite Marina at the time of the 1986 survey was approximately 3536 feet, which is about 79 feet above the original riverbed.

Data Collection

A bathymetric survey was conducted by Mussetter Engineering, Inc. on March 28-29. 2001, to provide additional, recent data on sedimentation conditions in the vicinity of Hite Marina. The survey was conducted using a boat-mounted Odom Hydrotrac® Portable Echosounder linked to a Satloc® DGPS mapping-grade Global Positioning System (GPS) receiver. The Echosounder and GPS were connected to a laptop computer and the Coastal Oceanographics Hypack Max® software was used to record the data. An aerial photograph of the reservoir in the vicinity of Hite Marina showing the 1986 USBR Range-lines and new transacts delineated by MEI at approximately 1,000-foot intervals were loaded into the software and registered to the latitude and longitude of the area. The integrated equipment allowed the location of the boat to be visually observed on the photograph in real-time during the survey.

The differentially corrected GPS that was used to perform the survey provides a horizontal accuracy, for each recorded point of less than 3.3 feet, and the accuracy of the depths recorded by the Echosounder is approximately +/-0.2 feet. Reservoir bottom elevations were determined from the survey by subtracting the recorded depths from the published lake elevation at the time of the survey (3662.84 feet). This procedure is similar to that used in the 1986 USBR surveys and is considered to be sufficiently accurate for purposes of this study.

A total of 15 transects, including 5 of the USBR 1986 range-lines for which data were available, were surveyed in the reach that extended from about 0.8 miles downstream from the mouth of North Wash (USBR Range-line 288) to about 500 feet upstream from the mouth of the Dirty Devil River (USBR Range-line 300) (Figure 6). In addition, a longitudinal profile of the reservoir bottom extending approximately 10 miles upstream from the mouth of the Dirty Devil River was also surveyed.

After completion of the bathymetric survey, the water surface elevation of the lake at the Hite Marina boat ramp relative to a number of control points was surveyed to provide information with which to check the published lake elevations. A summary of the relative elevation differences between the water-surface at the boat ramp and each of the control points is presented in Table 1. In addition, Figure 6 shows the approximate location of the control points in the vicinity of the boat ramp. The actual

elevations of the control points are to be determined by Jones and Demille Engineering. As of the date of this report, that survey had not been completed.

Table 1 . Relative elevation differences between the water-surface and surveyed control points at the Hite Marina boat ramp at the time of the 2001 survey.

Survey Control Point (CP)	Elevation Difference Above Reservoir (3662.84 ft)
CP1	17.72 ft
CP2	47.47 ft
CP3	51.67 ft
CP4	59.10 ft

DATA ANALYSIS

The data obtained from the bathymetric survey provide a direct measure of the current sedimentation conditions in the vicinity of Hite Marina. This information was used in conjunction with the historic data to estimate future sedimentation rates that can be used to estimate the useful life of the marina.

To facilitate the analysis, a station line was created that extended from the approximate location of USBR Range-line 286 to approximately 18 miles upstream beyond Dark Canyon near range-line 330. All previous and current surveys were plotted relative to the new station line, which allowed accurate determination ***of*** the distances between the surveyed transects. Profiles of the 1959 river surface prior to construction of Glen Canyon Dam, the 1986 USBR survey, and the 2001 MEI survey were then prepared based on the newly created station line (Figure 7). These profiles show that the sediment delta that was located thirteen miles upstream from Hite Marina near Dark Canyon. In 1986 has migrated downstream to near the mouth of the Dirty Devil River, only about two miles upstream from the marina. The current location of the crest of the sediment delta relative to Hite Marina boat ramp is shown in Figure 8. Plots showing the change in bed elevations between 1986 and 2001 at the 5 USBR Range-lines that were resurveyed are presented in Figures 9 through 13. The 2001 data indicates that the reservoir bottom in the vicinity of the boat ramp Is presently approximately elevation 3568 feet.

Sediment Volume

The volume of sediment that deposited in the portion of the reservoir upstream from USBR Range-fine 288 between 1986 and 2001 was estimated by comparing the profiles obtained from the 2001 survey with the earlier data. All of the 1986 surveyed range-lines were not published in USBR (1988): MEI obtained the missing data directly from the Sedimentation and River Hydraulics Group of the USBR. The comparison indicates that approximately 183,430 acre-feet has deposited in the

reach during the 15-year period. This equates to an average annual volume of about 12,200 acre-feet per year, which is about 39 percent less than the 19,950 acre-feet per year rate of sedimentation that occurred between 1963 and 1986, Several factors may account for the difference. First, the 2001 survey did not include the portion of the Colorado River downstream from USSR Range-line 288. As indicated in Figure 7, a small amount of deposition likely occurred downstream from Range-line 288 during the period that is not reflected in the recent survey. In addition, evaluation of historic flow records indicates that the average annual inflow to Lake Powell was approximately 15 percent greater, and the average annual peak flows were about 25 percent greater, during the period between 1963 and 1988 than they were between 1988 and 2001 (Figures 14 and 15). Considering that the relationship between water-discharge and sediment load is typically non-linear (i.e., a given increase in water discharge will cause a larger percentage increase in sediment load), the difference In runoff could account for much of the difference in sediment deposition. Finally, the 2001 survey extended only approximately 10 miles upstream from the mouth of the Dirty Devil River, and additional sedimentation may have occurred in the reach farther upstream during the period.

Figure 16 shows a schematic of the manner in which a typical sediment delta builds at the head of a reservoir. As illustrated in the figure, the front of the delta builds in the downstream direction as sediment is carried to and cascades down the front of the sediment wave. At the same time, the top of the delta builds upward at a slower rate as the portion of the reservoir upstream from the wave front adjusts toward a state of sediment transport equilibrium with the upstream supply. The reservoir geometry and the estimated annual sediment inflow to the reservoir during the 1986 to 2001 period were used to estimate the future rate at which the delta will build in the downstream direction, and the future rate at which the top of the delta will build upward.

A conservative estimate of the rate of downstream movement of the delta front was made by projecting the top of the existing delta between Dark Canyon and the Dirty Devil River, based on the 2001 survey, in the downstream direction, and computing the location of the delta front assuming that all of the inflowing sediment load would pass over the crest of the delta. This analysis indicates that the delta front will pass the boat ramp within the next 2 to 3 years. It should be recognized that this estimate is based on the average annual sediment inflow. If the next few years are wetter than normal, the time frame could be much shorter. When the delta front reaches the vicinity of the boat ramp, the elevation of the reservoir bottom will increase rapidly from its present elevation of about 3568 feet to about 3630 feet.

The rate at which the elevation of the sediment deposits on top of the delta will increase after the delta front passes the marina was estimated by assuming that 80 percent of the sediment will pass over the delta front, contributing to the downstream progression of the delta, and 20 percent of the sediment will be deposited in a wedge on the top of the delta. Currently, the slope of the delta-top in the reach between the front of the sediment wave in 1986 near Dark Canyon and the present front at the Dirty Devil River is about 2.6 feet per mile, compared to a topset slope of about 1 foot per mile upstream from Dark Canyon. Based on the steeper slope in the downstream portion of the reach, it was assumed that essentially all of the 20 percent portion of inflowing sediment load will deposit on top of the delta in the steeper reach between Dark Canyon and the delta front, at least until the top of the delta flattens to a slope

similar to that upstream from Dark Canyon. A plot of the historic and projected top-of-sediment deposits in the vicinity of the Hite Marina boat ramp based on the above assumptions is presented in Figure 17. Note that the abrupt increase In elevation between the years 2001 and about 2004 results from the passage of the delta front, and that the rate of increase in elevation after that time will be considerably slower than the historic rate. The elevation at the end of the boat ramp is approximately 3650 feet (Kerry Haut, personal communication, March 28,2001). Based on the projections illustrated in Figure 17, it is estimated that the top of the sediment deposits will reach elevation 3650 in the vicinity of the boat ramp within about the next 35 to 40 years.

In evaluating these results, it important to recognize that the estimated development of the sediment delta is based on a number of assumptions. While these assumptions have been made using the best available information and professional judgment, future conditions may ultimately be quite different. For example, as mentioned above, a series of wet years may significantly increase the rate ***of*** sedimentation in the reservoir, which could significantly decrease the time at which sediment becomes a problem at the marina. Also, as shown in Figure 2, the reservoir has been operated at elevations below 3650 feet for significant periods of time (most recently between July 1990 and April 1993). During such periods. the river will tend to cut into the sediment that has deposited at the higher elevations, transferring it farther downstream into the reservoir and potentially lowering the elevations in the vicinity of the boat ramp. More detailed hydraulic and sediment transport calculations in the area of interest would significantly provide more confidence in the result.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

An evaluation of historic sedimentation conditions in the upstream portion of Lake Powell was, conducted to assess the rate of future sedimentation in the vicinity of Hite Marina and to provide information with which to assess the useful life of the marina. The evaluation was conducted using available sediment information, including a 1986 survey that was conducted by the USBR and a recent survey in the vicinity of the marina that was conducted specifically for this study by MEI The following conclusions can be drawn from the analysis.

1. The annual rate of sedimentation in the reach between approximately 0.8 miles downstream from the mouth of North Wash and Dark Canyon between 1986 and 2001 was approximately 12,200 acre-feet. This rate is approximately 39 percent less than the documented rate of sedimentation in the Colorado River portion of the reservoir between closure of Glen Canyon Dam in March 1963 and 1986.

2. The front of the sediment delta in 1986 was located at approximately the mouth of Dark Canyon, which is about 13 miles upstream from Hite Marina.

3. At the present time, the front of the sediment delta is located near the mouth of the Dirty Devil River, less than 2 miles upstream from the marina.

4. As of 1986, approximately 79 feet of sediment had deposited in the bottom of the reservoir in the vicinity of Hite Marina. At the end of March 2001, the elevation of the reservoir bottom had increased by an additional approximately 33 feet.

5. Based on the average annual sedimentation rate between Dark Canyon and North Wash between 1986 and 2001 of 12,200 acre-feet, the front of the sediment delta can be expected to reach the vicinity of the boat ramp within the next 2 to 3 years, depending on the runoff conditions that occur during those years.

6. As the front of the delta passes the marina, the elevation of the bottom of the reservoir in this area will aggrade rapidly from its current elevation of about 3568 feet to approximately 3630 feet After passage of the delta front, the rate of aggradation will slow considerably, but the reservoir bottom will continue to aggrade. Conservative assumptions regarding the distribution of the sediment deposits indicate that the bottom of the reservoir will aggrade to elevation 3650 feet in the vicinity of Hite Marina within the next 35 to 40 years. Again, if a series of unusually wet years occurs during that time period, the rate of sedimentation may be significantly faster than indicated by this estimate.

Based on the inherent uncertainty in future runoff conditions and the associated amount of sediment that will be delivered to the reservoir, and approximate nature of this analysis on which these conclusions are based, it is strongly recommended that the reservoir bottom elevations be monitored at least on a yearly basis, particularly after a period of greater than normal runoff and sediment loads. It is also suggested that a more accurate estimate of future sedimentation rates in the vicinity of the marina could be made by employing a one-dimensional sediment routing model, such as the Corps of Engineers HEC-6 model. Use of such a model would provide a means of evaluating the change in hydraulic conditions and sediment transport capacity as the reservoir fills with sediment, and would allow a series of runs to be made that would provide a means of evaluating the effects of the highly variable runoff and sediment load conditions that, occur from year-to-year in the Colorado River.

REFERENCES

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